Iowa Barrier Rail Mix Design Development

In 1998, the Iowa DOT did an investigation (MLR-98-01) into slip formed median barrier rail to determine the cause of deterioration in the rails. The rails exhibited severe map cracking, spalling, and leaching. Large voids were typically found and further investigation revealed air contents of less than 2 percent and spacing factors as poor as 0.278 mm (0.011 in).

Barrier rail cores exhibiting large voids



Poor consolidation with Class D mix



Poor workability produces poor performance



The standard mix design for barrier rails is the Iowa Class D mix design. The mix is a 50% coarse, 50% fine aggregate with a high paste content. (See Figure 1) The Class D mix typically yields variable workability in slip formed rails and usually is fairly poor.

In 1999, Kurtis Keifer from Allied Construction contacted the Materials Office to determine if something better could be done for slip form bridge rail than using the Class D mix design. Allied Construction was supplying concrete to Dormark Construction on dual bridges over the railroad on US 18 in Floyd County, near Rudd. The typical problem with the Class D mix design is the contractor must place the mix at ¾" slump or less or the concrete will weep. It is difficult to entrain air in concrete with that low slump and Allied was able to achieve air contents no greater than 5.5%, using AEA at a rate of 25 oz. per cwt.

We decided to investigate the use of well-graded aggregates in conjunction with a reduced cement (paste) content to facilitate placement and air entraining of the concrete. This mix design was labeled as BR. (Figure 1) The BR mix design used the Shilstone principles of well-graded aggregates (see Figures 2-7), this

along with reduced paste gives a more workable mix for slip form, since the concrete is stacking aggregate instead of paste.

The BR mix design utilized the use of $\frac{1}{4}$ " limestone chips to achieve a better gradation. The mix required AEA at a rate of 8 oz. per cwt and achieved 7.4% plastic air content. Slump was increased to 1" for production. Slump was actually increased to 1 $\frac{1}{4}$ ", with no affect on weeping. (See Figure 8)

Dormark and Larry Wishon from Manatts contacted the DOT concerning a retrofit rail on I-35 SB near Ames. A similar mix design was developed with very good results. The mix had a 0.395 w/c ratio with 1.5" slump. 7 and 28 day compressive strengths were 6150 and 7295, respectively.

In fall of 1999, the BR mix design was used on median barrier rail on I-35/80 in Des Moines from Merle Hay Road to 2nd Avenue interchange. Dormark was the contractor and Larry Wishon from Manatt's provided the mix design. The BR mix design allowed better placement characteristics and air entraining capacity than the Class D mix design.

Another development using BR mixes was the use of Class V gravel in a mix on IA 92 bridge rail in Pottawattamie county. The contractor was very impressed with the placement of this mix. The greater ease of placement is primarily due to the use of a rounded aggregate. (Figure 9)

Other recent changes, include the use of ground granulated blast furnace slag in barrier rail on IA 5 in Des Moines. (See Figures 10-11) The use of slag in the mix at approximately 20% replacement and fly ash at 10 to 15% replacement helps produce a very workable BR mix. (See Figure 12) Higher percentage replacement of cement replacement with slag (35%) and fly ash (15%) were used on US 151 at Anamosa. (Figure 13 – 14)

It was noted that the median barrier would allow a higher slump to be placed if the median barrier had a reinforcing cage similar to bridge rail, instead of feeding continuous bars into the mule. (Figure 15 & 16) Design has changed in 2004 to use a reinforcing cage for median barrier rail. (Figure 17 & 18)

Since 2006, after noticeable improvements in workability in slip form barrier and bridge rail, the Shilstone method of well graded aggregate mix design (or BR mix) is now required for all slip form rail. The major workability and placement problems have been reduced since the BR mix has been used. Class D has been eliminated for slip form rail and Class C is now required on fixed form rail.

Mix Design

D-57

Cement 709 lbs

Water 246 lbs

Coarse 1418 lbs

■ Fine 1413 lbs

AEA as needed

No water reducer

BR-1

Cement 603 lbs

Water 259 lbs

Coarse 1320 lbs

Intermediate 440 lbs

■ Fine 992 lbs

AEA as needed

Water reducer

Figure 2

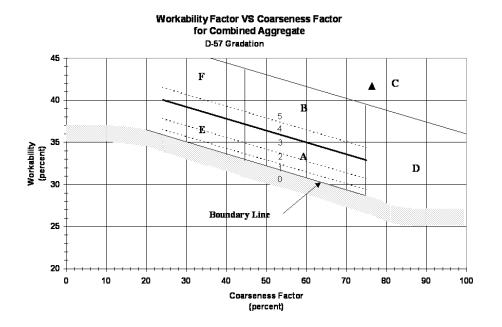
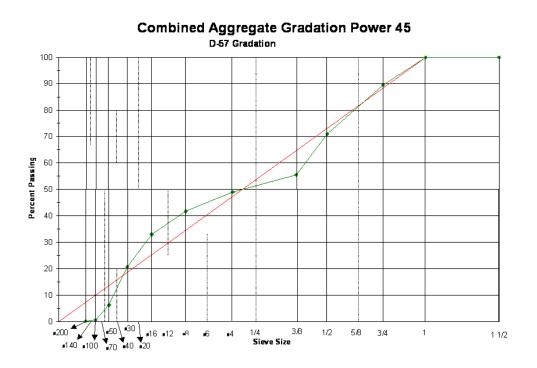


Figure 3



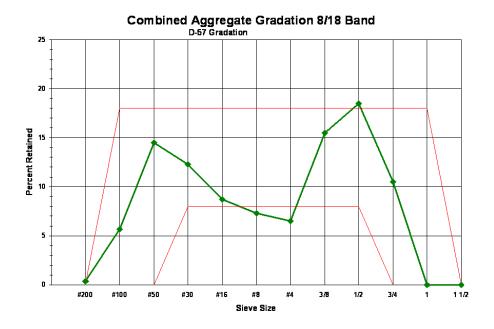


Figure 5

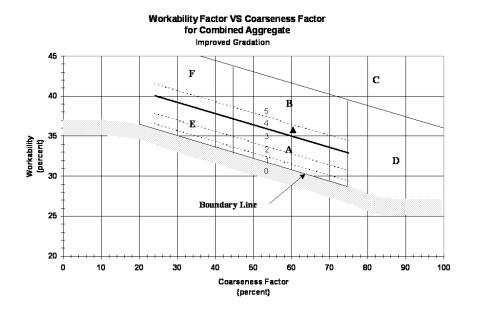
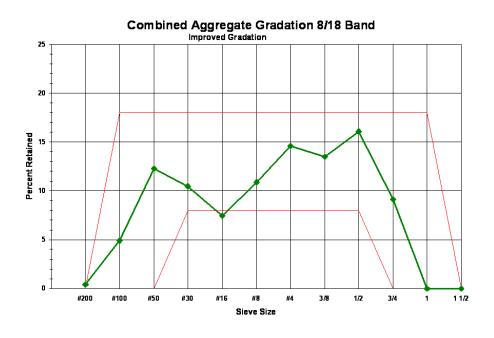




Figure 7



Results

<u>D-57</u>

- 28 day comp. strength
 - 5750 psi
- Cracks per rail
 - **55, 54**
- AEA @25 oz. -5.5% air
- Slump 0" to 3/4"
- Permeability 7000

BR-1

- 28 day comp. Strength
 - 6800 psi
- Cracks per rail
 - **26, 11**
- AEA @8 oz. 7.4% air
- Slump 3/4" to 1 1/2"
- Permeabililty 3600

Figure 9 Pott Co Rail



Figure 10 – IA 5 Rail



Figure 11 IA 5 Rail Closeup



Figure 12 IA 5 Mix Design

GENERAL INFORMATION
PROJECT:
PROJECT TITLE: IA 5 over IA 28 RAIL3AGG MIX TYPE: MIX NUMBER: DATE: 06/28/00

MATERIALS	Source		Type/Class	SPG	Percent	Percent
CEMENT:	HUMBOLT KS (MONAF	I/II		3.14		
FLY ASH:	OTTUMWA	С		2.61	10.00	
MINERAL ADMIXTURE:					0.00	
SILICA FUME SLURRY:					0.00	
FINE AGGREGATE:	A77520			2.65	42.00	
COARSE AGGREGATE:	A85006			2.57	52.20	90.00
INTERMEDIATE AGGREGATE:	A85006			2.57	5.80	10.00
AIR ENTRAINING AGENT:	TYPICAL					
RETARDER:						
WATER REDUCER:	TYPICAL					
SUPER WATER REDUCER:						
ACCELERATOR:						
DESIGN W/C(+FLY ASH):	0.39					
DESIGN SLUMP:	1.0 (maximum)					
DESIGN AIR CONTENT:	6.0					

Volume	Volume						Weight	Weight
ft3	ft3						lbs	lbs
Batch Size	Batch Size						Batch Size	Batch Size
1.0 yd3	1.0 ft3						1.0 ft3	1.0 yd3
2.7678	0.1025	Х	3.14	Х	62.4	=	20.1	542
0.3700	0.0137	Х	2.61	Χ	62.4	=	2.2	60
0.0000	0.0000						0.0	0
0.0000	0.0000						0.0	0
3.7660	0.1395	Х	1.00	Χ	62.4	=	8.7	235
7.7600	0.2874	Х	2.65	Х	62.4	=	47.5	1283
9.6446	0.3572	Х	2.57	Χ	62.4	=	57.3	1547
1.0716	0.0397	Х	2.57	Χ	62.4	=	6.4	172
1.6200	0.0600	Х	0.00	Х	62.4	=	0.0	0
27.0000	1.0000						142.2	3839
60.3								
	ft3 Batch Size 1.0 yd3 2.7678 0.3700 0.0000 0.0000 3.7660 7.7600 9.6446 1.0716 1.6200	ft3 ft3 Batch Size Batch Size 1.0 yd3 1.0 ft3 2.7678 0.1025 0.3700 0.0137 0.0000 0.0000 0.0000 0.0000 3.7660 0.1395 7.7600 0.2874 9.6446 0.3572 1.0716 0.0397 1.6200 0.0600 27.0000 1.0000 25.6 1.0000	ft3 ft3 Batch Size Batch Size 1.0 yd3 1.0 ft3 2.7678 0.1025 X 0.3700 0.0137 X 0.0000 0.0000 X 0.0000 0.0000 X 3.7660 0.1395 X 7.7600 0.2874 X 9.6446 0.3572 X 1.0716 0.0397 X 1.6200 0.0600 X 27.0000 1.0000 25.6	ft3 ft3 Batch Size Batch Size 1.0 yd3 1.0 ft3 2.7678 0.1025 X 0.3700 0.0137 X 2.61 0.0000 0.0000	ft3	ft3	ft3 Batch Size 1.0 yd3 1.0 ft3 2.7678 0.1025 X 3.14 X 62.4 = 0.3700 0.0137 X 2.61 X 62.4 = 0.0000 0.0000 0.0000 3.7660 0.1395 X 1.00 X 62.4 = 7.7600 0.2874 X 2.65 X 62.4 = 9.6446 0.3572 X 2.57 X 62.4 = 1.0716 0.0397 X 2.57 X 62.4 = 1.6200 0.0600 X 0.000 X 0.000 X 62.4 = 27.0000 1.0000	ft3 ft3 Batch Size 1.0 yd3 Batch Size 1.0 ft3 Ibs Batch Size 1.0 ft3 2.7678 0.1025 X 3.14 X 62.4 = 20.1 0.3700 0.0137 X 2.61 X 62.4 = 2.2 0.0000 0.0000 0.00 0.0 0.0 0.0 0.0 3.7660 0.1395 X 1.00 X 62.4 = 8.7 7.7600 0.2874 X 2.65 X 62.4 = 47.5 9.6446 0.3572 X 2.57 X 62.4 = 57.3 1.0716 0.0397 X 2.57 X 62.4 = 6.4 1.6200 0.0600 X 0.00 X 62.4 = 0.0 27.0000 1.0000 X 0.00 X 62.4 = 0.0

CHEMICAL ADMIXTURES

Mortar Content (% pass)

56.6

		_						Rate	Rate
								ml	ml
	Rate							Batch Size	Batch Size
	oz/100 lbs cementitious							1.0 ft3	1.0 yd3
AIR ENTRAINING AGENT:	NORMAL DOSAGE	22.32	Х	######	Х	29.57	=	#VALUE!	#VALUE!
RETARDER:									
WATER REDUCER:	1/2 TO FULL DOSAGE	22.32	Х	######	Х	29.57	=	#VALUE!	#VALUE!
SUPER WATER REDUCER:									
ACCELERATOR:									

Figure 13 US 151 Rail



Figure 14 US 151 Rail Closeup



0 installation Surface 0 Normal Joint Spacing 0 4 Bart 2" obser Precest Section or each and-Cont in Place Service ELEVATION TYPE 2 Cost in Place TOP VIEW 8 Renovae Lap Θ Main ONB d DETAILS OF BARRIER FACE DETAIL "B" Special Shapping for Barrier over Intake TYPICAL SECTION é To be the rest integral right supporting and international displayers, quickly objected and international restriction of the standard for international restrictions of the standard for international restrictions.

 To the formulation of the restriction of the right 0 The precent better units shall have 2 approved infuring devices placed in, the top of each better section, After placement, and critical formed by the lifting devices shall be grouted with no projections above the better terfaces. 6666 Inperif Janks are necessary to match entiting 'E' and 'E' Joints and the expansion setural shall conform to shops of borriers to sealer in required. Free bud per lines] foot for "Berney Longreto iff-446" shell be considered full componistion for construction of enerate larner as detailed herein including reinforcing steel. Devets shall be enther macalled in supporting surface when placed or installed in drilled lates using aposit carent or grout approved by the angineer. Epony costed steel bers are required, see Section 4151.028 of specifications. bleats share herein one for construction of a typical concents because. The barrier may be cast in please or construction of the present units at the option of the conspection united specified otherwise may be upon plates. Before a "Tabulation of Concrete Barrier" and Project full as ten peertin details. langmete shell be Class "O" Structural Concrete placed and inspired as specified in Section 2407,14 or current specifications, in building approved by the engineer. The contractor shall equation a Ω^* maximum distance supporting surface to 10° radius break. lowa Department of Transportation
Highway Division DETAILS OF CONCRETE BARRIER
(FULL SECTION) SJANDARD ROAD PLAN detacls may be sub-

Figure 15 Design Standard Median Rail until 2004



ELEVATION

CAMPINE ANTE:
Controller

Contr

44" CONCRETE MEDIAN BARRIER FULL SECTIONS

Figure 17 Design Standard Median Rail 2004



